



National Aeronautics and Space Administration

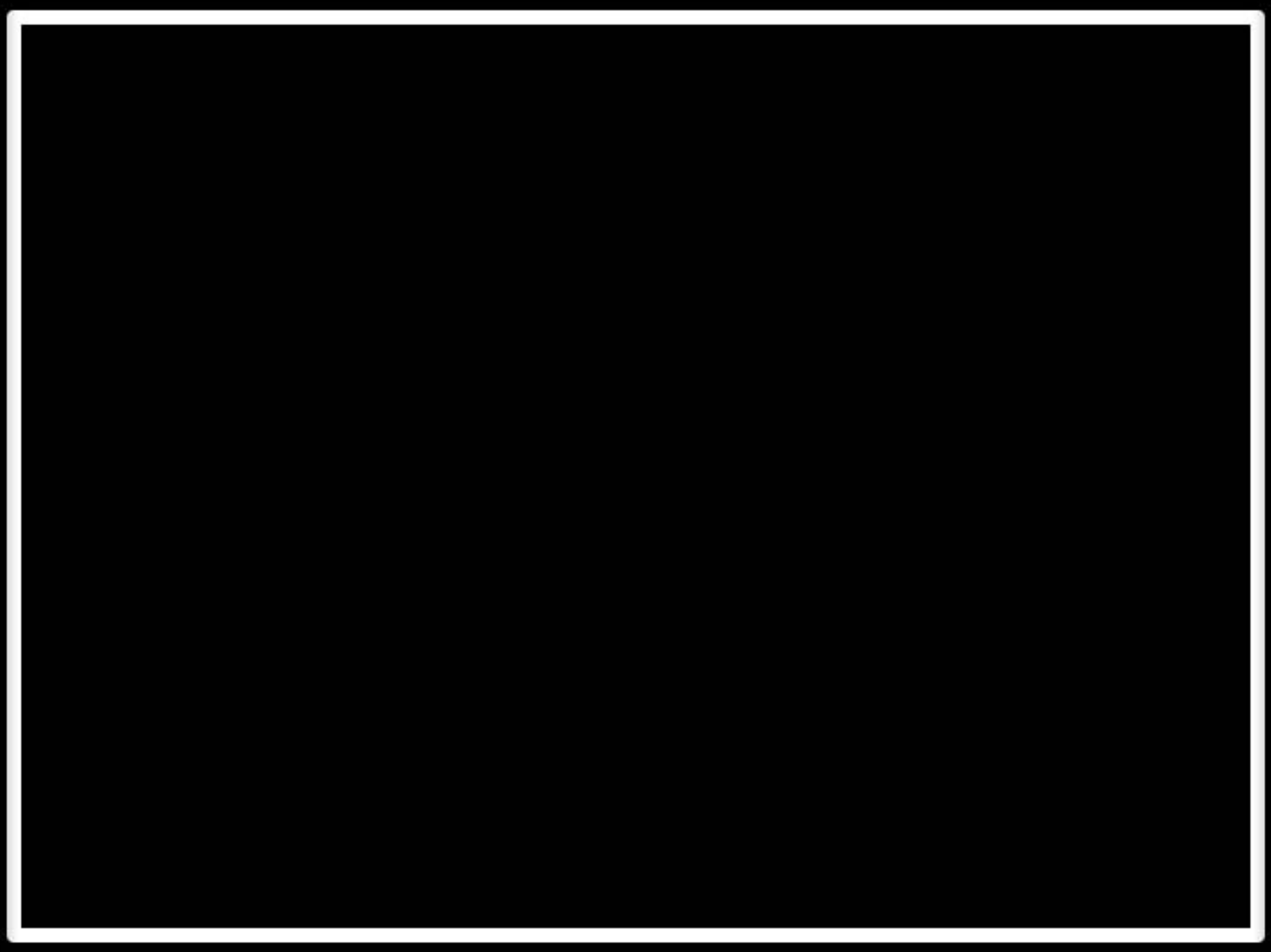
Evolution to Space

Jacob Cohen, Ph.D.

Chief Scientist

NASA Ames Research Center

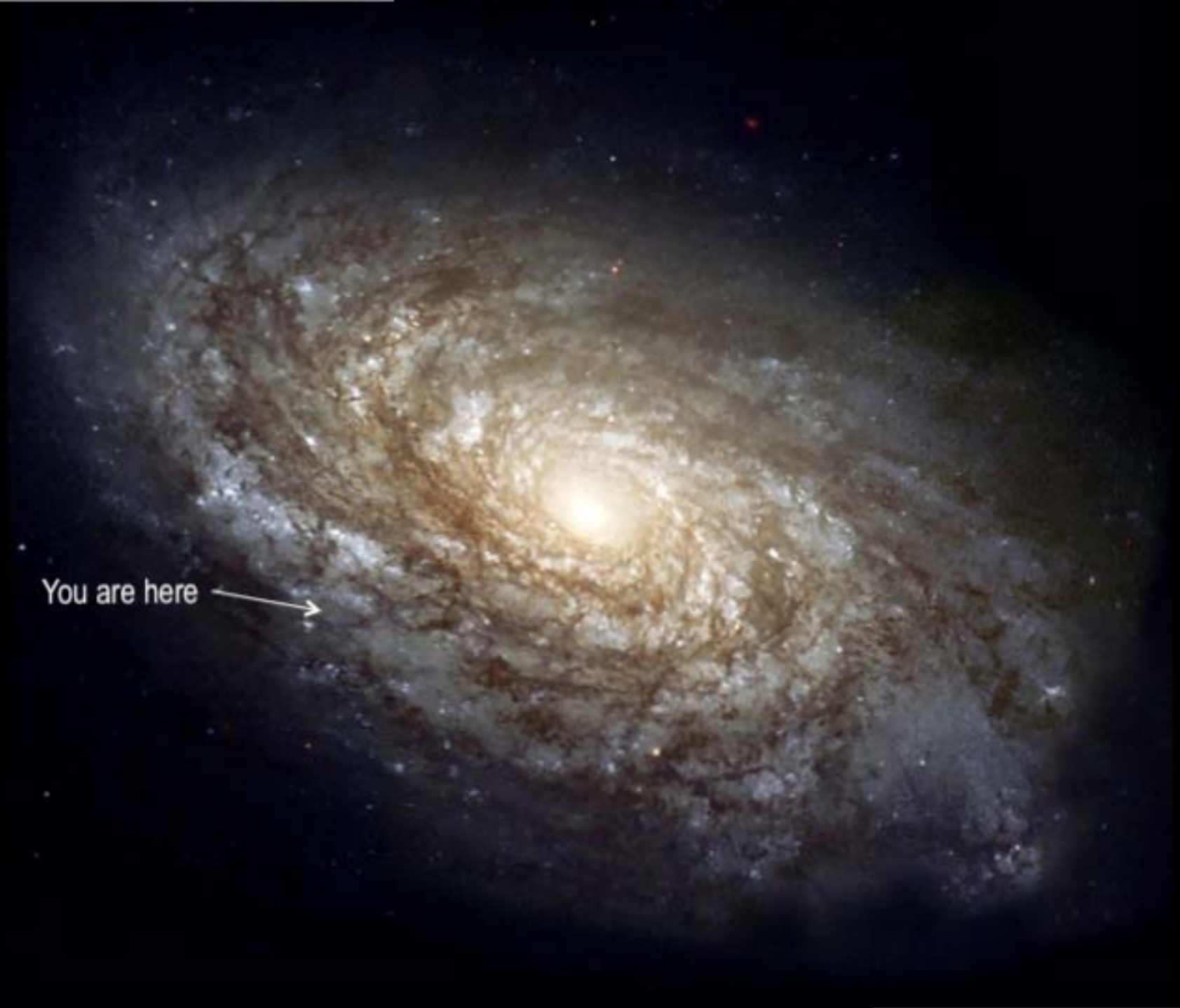
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Disruptive Events Lead To New Opportunities





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Standardization Speeds Up The Evolution Wheel



Inheritance, Variation and Selection

Standardization does not mean regulation.

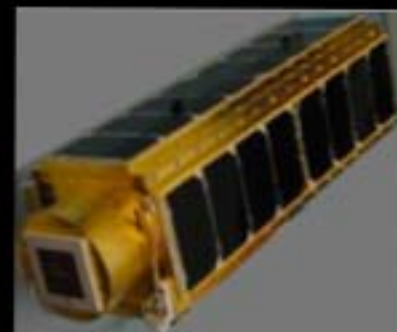
Standardization: The process of developing and implementing technical standards. The goals of standardization can be to help with independence of single suppliers (commoditization), compatibility, interoperability, safety, repeatability, or quality. (en.wikipedia.org)

Regulation: A principle, rule, or law designed to control or govern conduct.
(thefreedictionary.com)

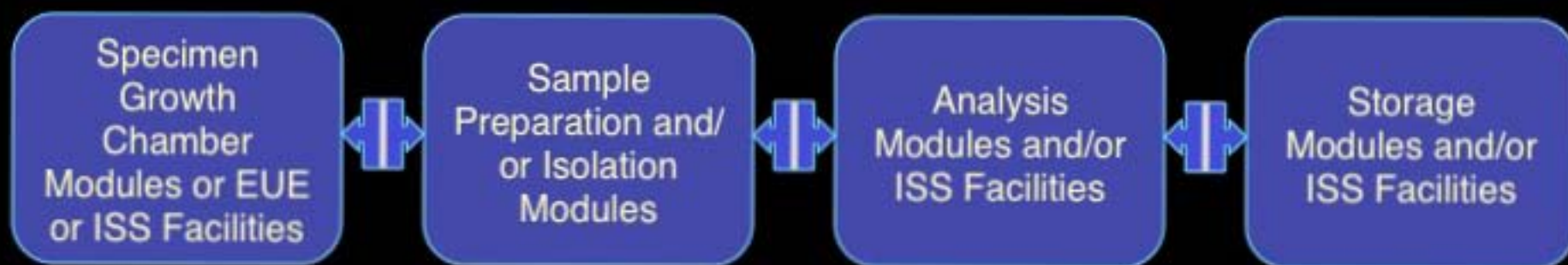
Modularization = Predictability of Standardization
+
Flexibility of Subcomponent Customization



IBM



A method to maximize the science return from the ISS while reducing risk, schedule and ultimately cost per experimental unit.



Reference: WetLab 2, NanoLab and Cell Science hardware as proposed by J. Cohen



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"Moon Landscape" by
Petr Ginz (1942)



The March 22, 1952 issue of Collier's Magazine



Nov. 3, 1957
Laika, first
animal in space



April 12, 1961
Gagarin first
human in space



July 21, 1969
Armstrong and
Aldrin on the Moon

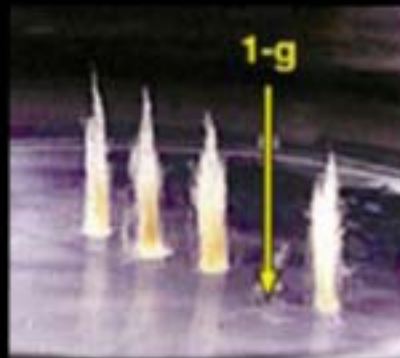


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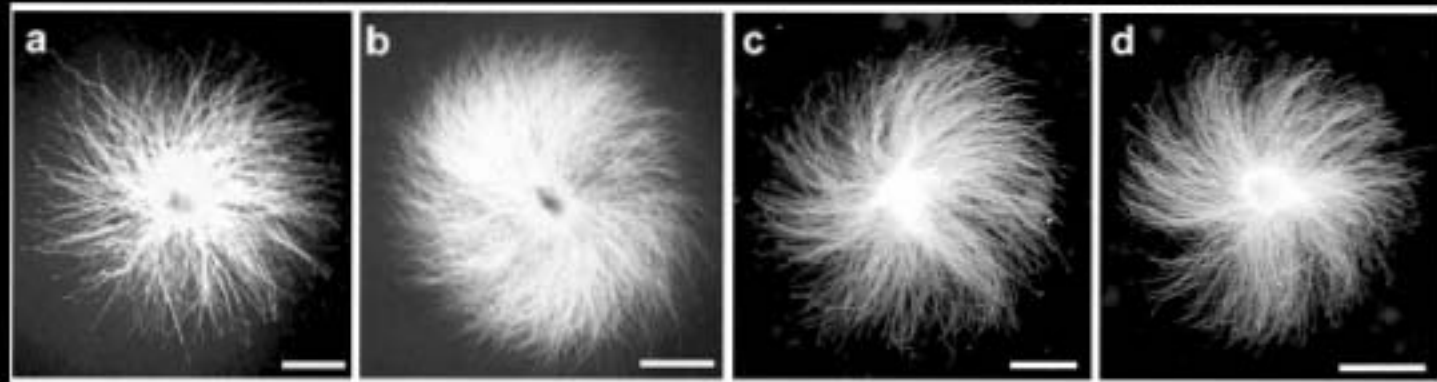
Microgravity and Moss Growth

On Earth



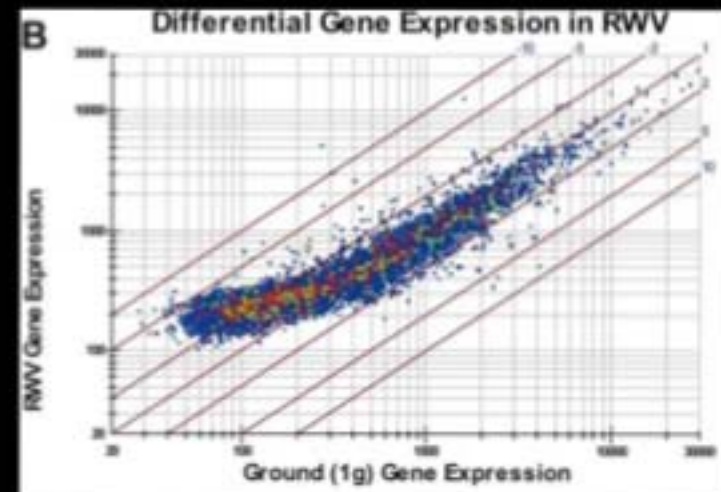
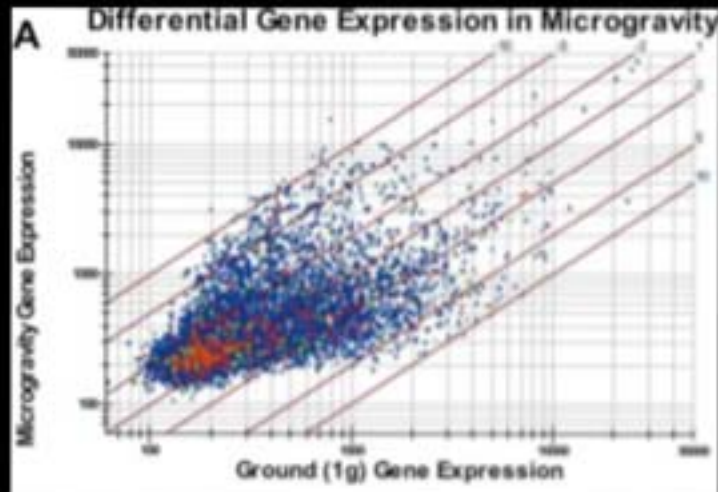
STS-87

STS-107



Gravitropic *Ceratodon purpureus* moss cells default to spiral growth in spaceflight microgravity.

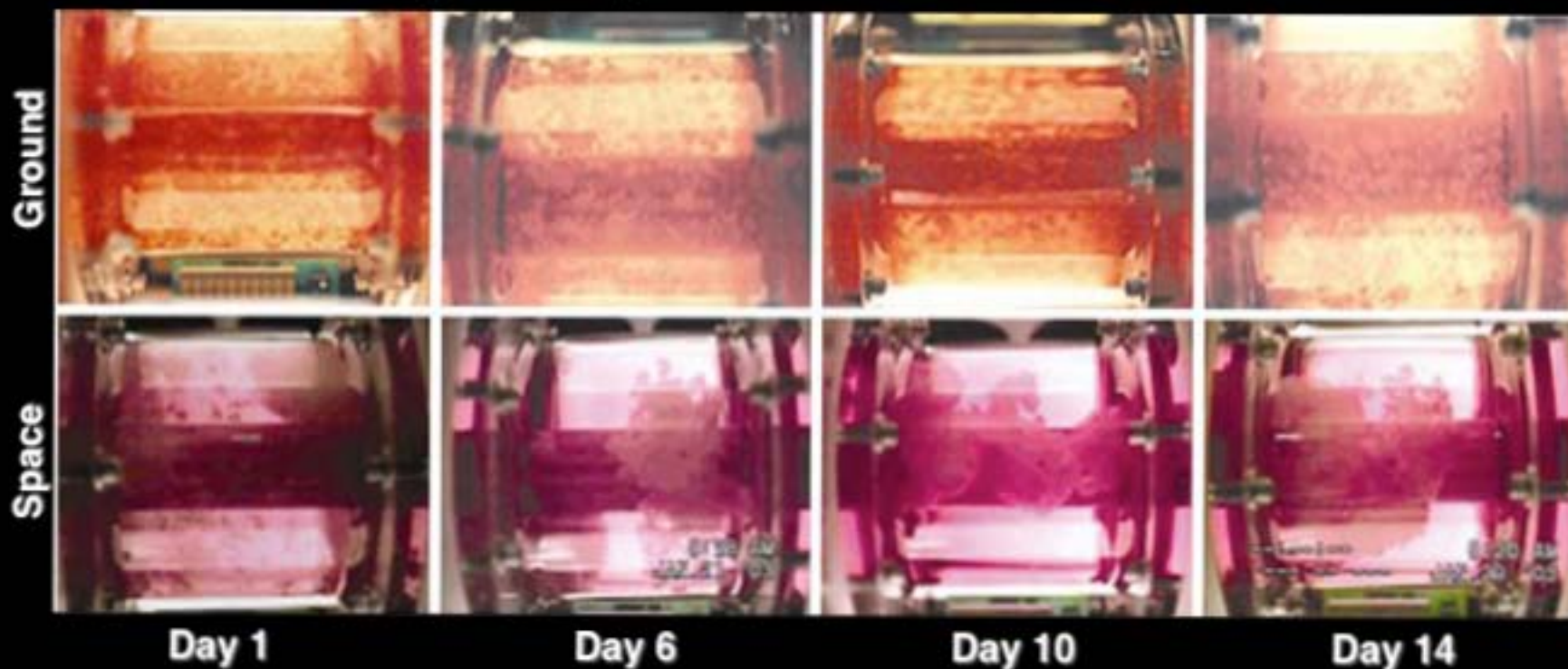
Microgravity and Gene Expression



Gene array. Each cell culture condition including microgravity (A) and terrestrial rotating wall vessel (B) is compared with a static nonadherent bag culture. Sheer stress proteins and heat shock proteins are shown in green, and transcription factors are in red. More than 1,600 (1,632) change more than the specific threshold of threefold up and down in the flight (microgravity) culture (A) and more than 900 genes (914) changed in the terrestrial RWV culture (B); only a few genes (5) changed in a terrestrial centrifuge culture (not shown).

(Hammond, 2000)

Microgravity and Tissue Culture



Formation of large prostate cancer organoids with the 3D rotating wall vessel bioreactor in space. Much larger prostate organoids were formed in space (30-50 cm across) as compared to the parallel ground study (3-5 cm) despite no difference in glucose utilization rate between ground and space studies.

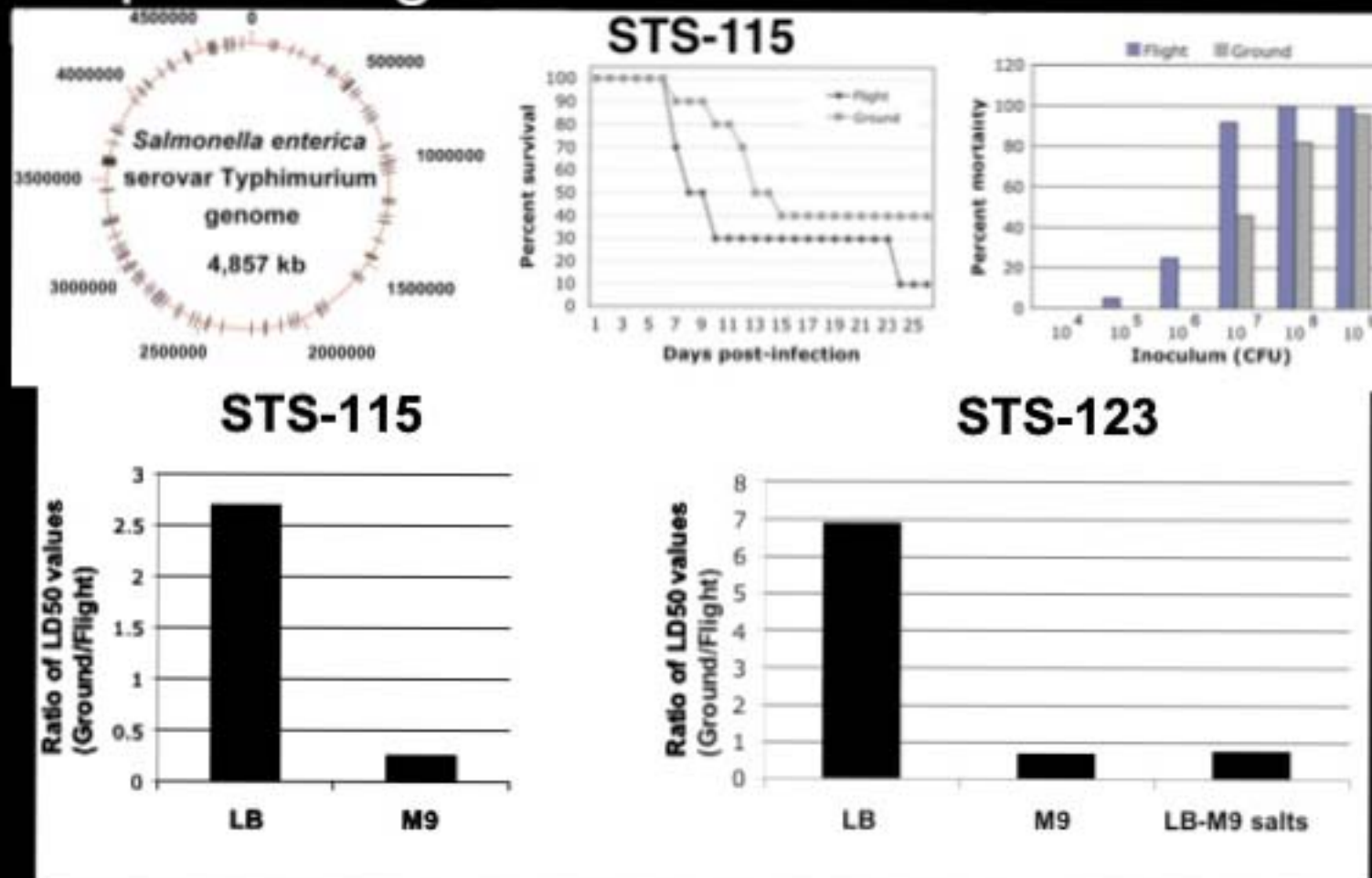
(Wang, 2005)



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Space Flight and Microbial Virulence



Transient virulence increase of *S. typhimurium* in response to spaceflight in LB medium is not observed in M9 minimal medium or LB medium supplemented with M9 salts.

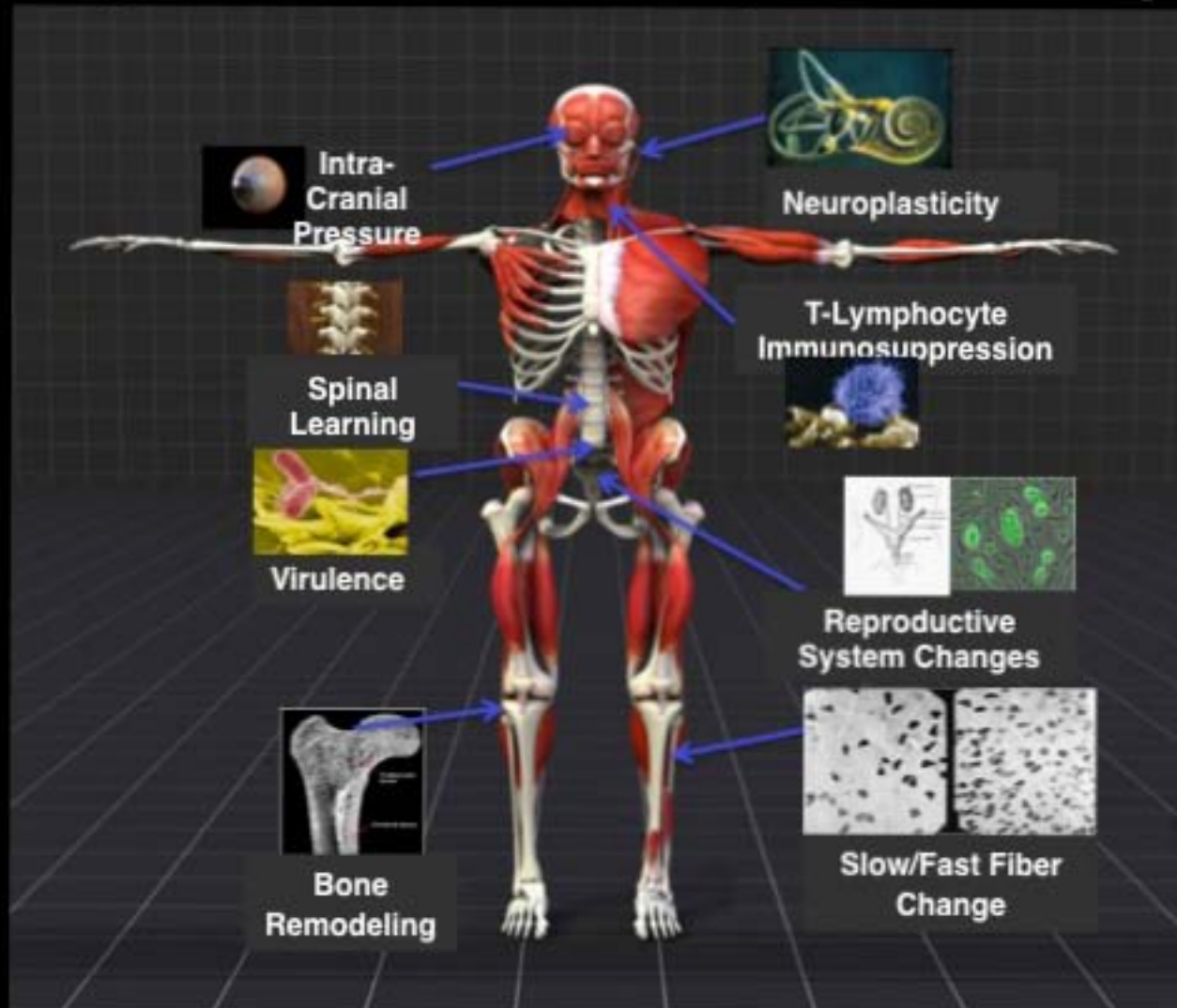
(Nickerson Lab; STS-115 and STS-123)



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Examples of Human Responses to Space





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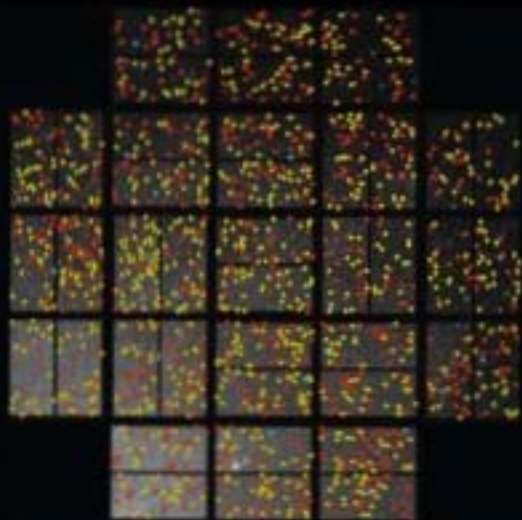
Not to Scale



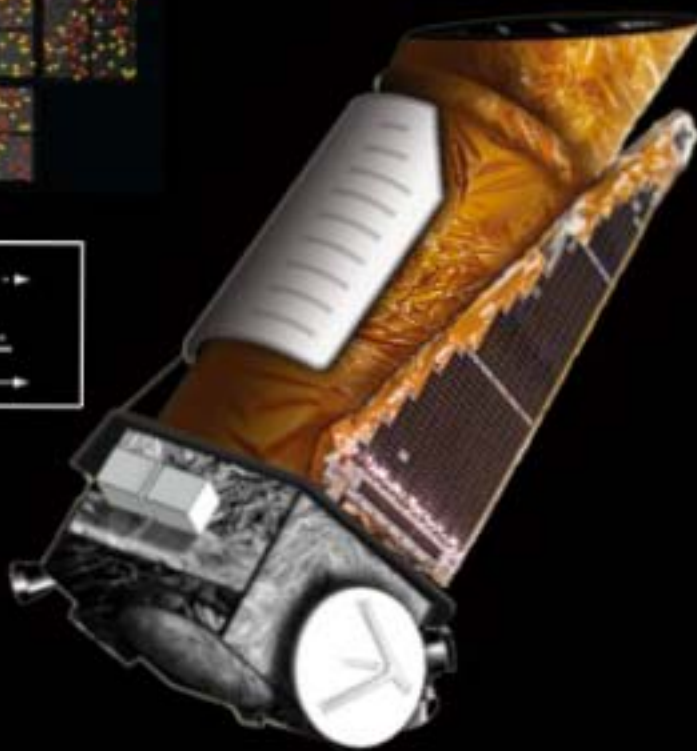
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Ames

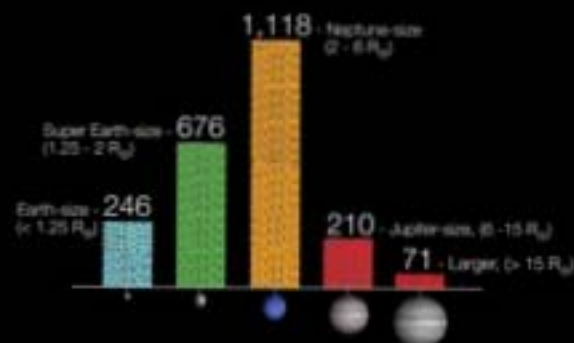
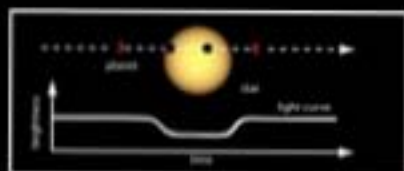
Discovery Innovations Solutions



Kepler



As of February 27, 2012
1,790 host stars
2,321 planet candidates
74 confirmed planets





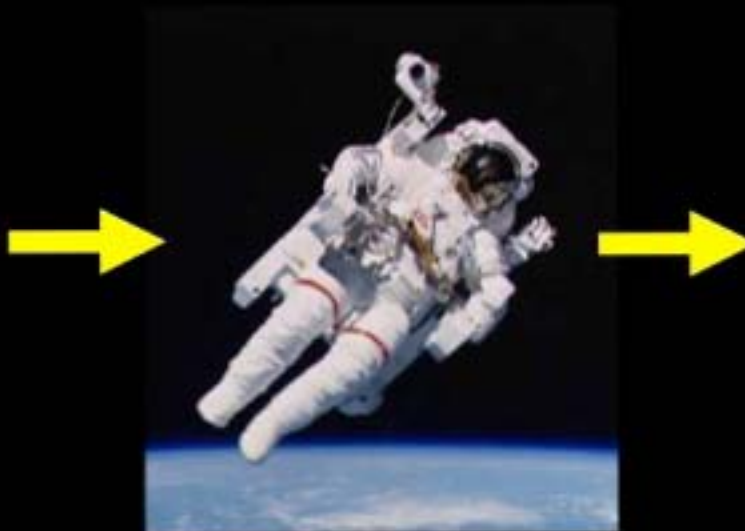
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Mass Breakdown Requirements (Per Person-Day)

DAILY INPUTS - NOMINAL

	kg
Oxygen	0.84
Food Solids	0.62
Water in Food	1.15
Food Prep Water	0.79
Drink	1.62
Hand/Face Wash Water	1.82
Shower Water	5.45
Clothes Wash Water	12.50
Dish Wash Water	5.45
Flush Water	0.50
<hr/>	
TOTAL	30.74



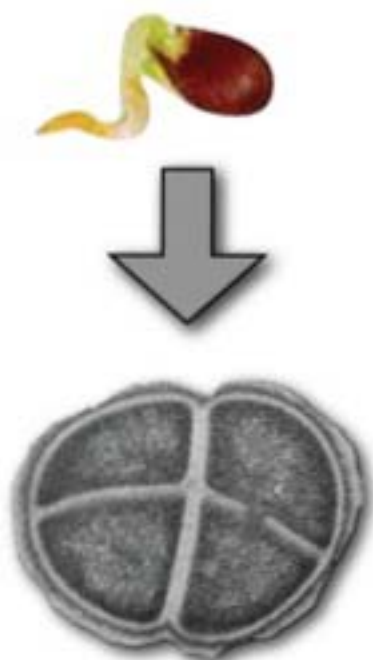
Life Support

11.3 Metric Tons Per Person-Year

DAILY OUTPUTS - NOMINAL

	kg
Carbon Dioxide	1.00
Respiration and Perspiration Water	2.28
Urine	1.50
Feces Water	0.09
Sweat Solids	0.02
Urine Solids	0.06
Feces Solids	0.03
Hygiene Water	6.68
Clothes Wash Water	11.90
Clothes Wash	0.60
Latent Water	
Other Latent Water	0.65
Dish Wash Water	5.43
Flush Water	0.50
<hr/>	
TOTAL	30.74

Biology is the right tool for exploration

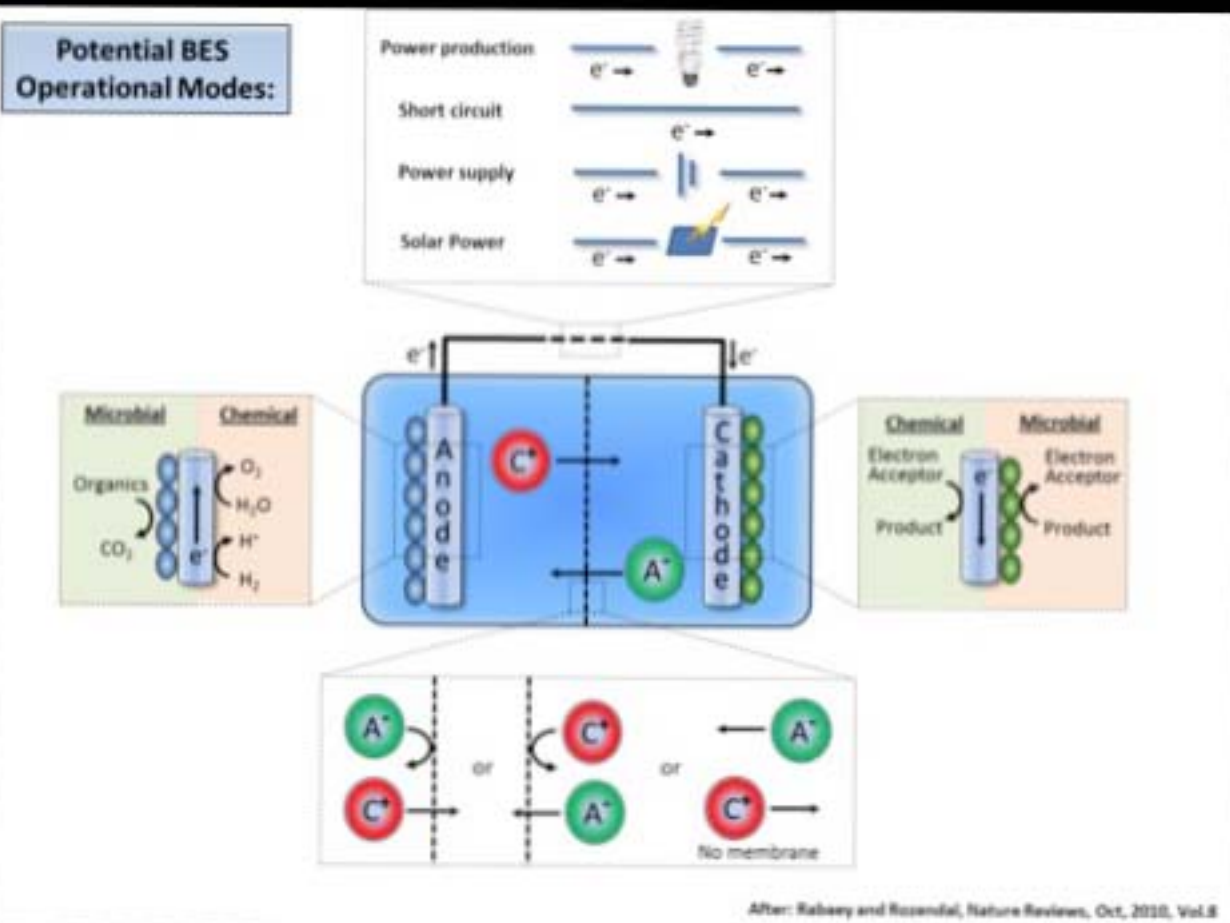


- Low mass
- Self replicating
- Fast growing
- Adaptable
- Flexible host
- A manufacturing technology


The Potential of Synthetic Biology in Space



Bioelectrochemical systems utilize microorganisms that are capable of generating electricity during the catalysis of substrates (microbial fuel cell - MFC) and/or utilizing electrical energy as the metabolic energy source for growth (reverse MFC).



Take it a step further: How about a synthetic biology ion engine?



**The key to long term success in life is
imagination, persistence, and compassion**

From the Past
From the Future
The Drive of Now
Working Together Humanity Will Conquer
The Exploration of the Time and Space Frontier

Thank You



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NASA Ames Research Center



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Ames Today



- 2480 employees*
- ≈900M + annual revenue
(including reimbursable)
- *in addition, 900 students,
summer 2012

- Science
 - Space, Earth, Biological Sciences
 - Astrobiology, Lunar Science
- Exploration Systems
 - Exploration Technology Development
 - Thermal Protection Systems
 - Supercomputing
- Projects and Missions
- Aeronautics & Aviation
 - NextGen Airspace Systems
 - Fundamental Aeronautics
 - Aviation Safety
 - Green Aviation
- Affordable Small Satellites
- Innovation, Education, & Entrepreneurial Collaborations
 - NASA Research Park



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capabilities

Space Sciences

- Extraterrestrial Planets
- Infrared Astronomy
- Planetary Science
- Heliohydric Data Analysis
- Lunar Science
- Astrobiology
- Astrochemistry
- Mars Climate Modeling Center

Earth Sciences

- Atmospheric Sciences
- Biospheric Sciences
- Climate Modeling
- Ecological Forecasting
- Adaptive Science Campaigns
- Unmanned Aircraft Systems (UAS)

Biological Sciences

- Molecular & Cell Biology
- Synthetic Biology
- Gravitational Biology
- Radiation Measurement Technologies
- ISS Payloads

Biotechnology

- Biomedical Engineering
- Space Medicine
- Environmental and Life Support Systems
- Synthetic Biology

Intelligent Systems

- Robotics
- Computer Systems and Engineering
- Software Engineering
- Intelligent/Adaptive Systems

High Performance Computing

- Petascale Systems Engineering
- Mass Data Storage
- Fundamental Modeling and Simulation
- Applied Modeling and Simulation
- Application Optimization
- Data Analysis and Visualization
- High-Performance Networks
- IT Security

Advanced Aerospace Materials and Devices

- Nanoscience
- Nanotechnology
- Bioengineering
- Computer Systems and Engineering
- Software Engineering
- Mathematical Modeling and Analysis
- Data Visualization

Space Transportation Technology/Thermal Protection Systems

- Chemistry/Chemical Engineering
- Advanced Materials and Processing Science
- Materials Engineering
- Thermal Systems
- Thermal Structures
- Aerothermodynamics
- Hyper-Thermal Testing
- System Architecture

Human Systems Integration

- Human-Machine Interaction
- Human Performance
- Integration and Training

Small Spacecraft

- Engineering Design
- Mission Operations
- Mission Design, Fabrication and Test

Airspace Systems

- Air Traffic Management Systems
- Fundamental Human Factors Research
- Human Factors Engineering
- Advanced Analysis and Design Method Development
- Crew Systems and Aviation Operations
- Advanced Experimentation and Testing Technologies

Applied Aerospace and Information Technology

- Sensors and Data Acquisition
- Autotests
- Control Systems, Guidance and Navigation
- Communications Networks and Engineering
- Computer Systems and Engineering
- Software Engineering
- Data Acquisition, Management and Storage
- Neural Networks and Systems
- Intelligent/Adaptive Systems
- Mathematical Modeling and Analysis
- Data Visualization
- Aerospace Systems Concept Development and Technology Assessment
- Advanced Analysis and Design Method Development
- Flight Dynamics
- Applied Aerodynamics
- Aeroelasticity
- Aerodynamics
- Thermal Systems
- Advanced Experimentation and Testing Technologies
- Simulation/Flight Research Systems
- Engineering Risk Assessment

capabilities



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Current Active Facilities, 2009 ➔



**National Full Scale Aerodynamic
Complex, 80x120 Wind Tunnel**



**Vertical Motion
Simulator**



**Small Spacecraft
Development Facility**



Unitary Plan Wind Tunnel



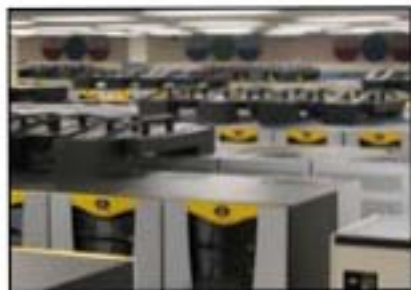
SOFIA



Machine Shops



Small Satellite Lab



**Pleiades - Columbia
Super Computer**



Ballistic Range



Arc Jets



Image copyright Dariusz Jezewski



Airfield and Hangars

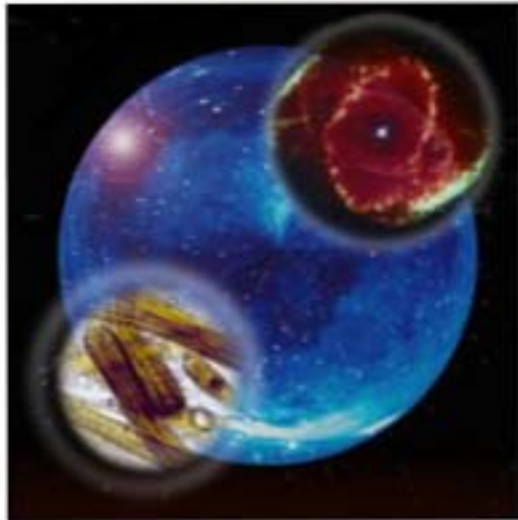


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Virtual Institutes at Ames

Astrobiology Institute



Scientific Study of life

NASA Lunar Science Institute



**Advance the field of
lunar science**

NASA Aeronautics Research Institute



**Creating new tools and technologies
for reducing air traffic congestion
and environmental impacts,
improving safety, and designing
aircraft**



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NASA Research Park

Innovative Collaboration in Science, Engineering & Education

90+ Partners Today

University Associates

Google-North East Section

University of California/UARC-Bldg. 555

M2MI Corporation-Bldg.19

Carnegie Mellon University-Bldg. 23

San Jose State University

-Metropolitan Technology

Center in Bldg. 583C

Foothill-De Anza Community College

United Negro College Fund Special

Programs Corporation-Bldg.19

Space Technology Center

-San Jose State, Stanford, Santa Clara Univ.,

Utah State Univ. /Micro Satellite Classes

Kentucky Science & Technology Corporation-Bldg.19

Bloom Energy-Bldg. 543 (Fuel Cell Research)

Industry Partners-Bldg. 566 & 19

UAV Center-Bldg.18

International Space University





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WHY WE DO WHAT WE DO—PART ONE

FOUR THINGS NASA DOES





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Number One: Improve Life on Earth

- **Aeronautics**
 - Next Gen
 - Environmentally Responsible Aviation
 - New Initiatives
 - **Autonomy, Electric Aviation**
- **Earth Climate studies**
 - **Site-specific Climate prediction**





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Number Two: Conduct Earth and Space Science

- Astrophysics
 - **Origin/Distribution of Life in the Universe**
- Planetary science
 - **Moon**
 - **Mars**
 - **Asteroids**
- Earth Science
 - **Venture class**
- Heliospheric Physics
 - **IRIS**



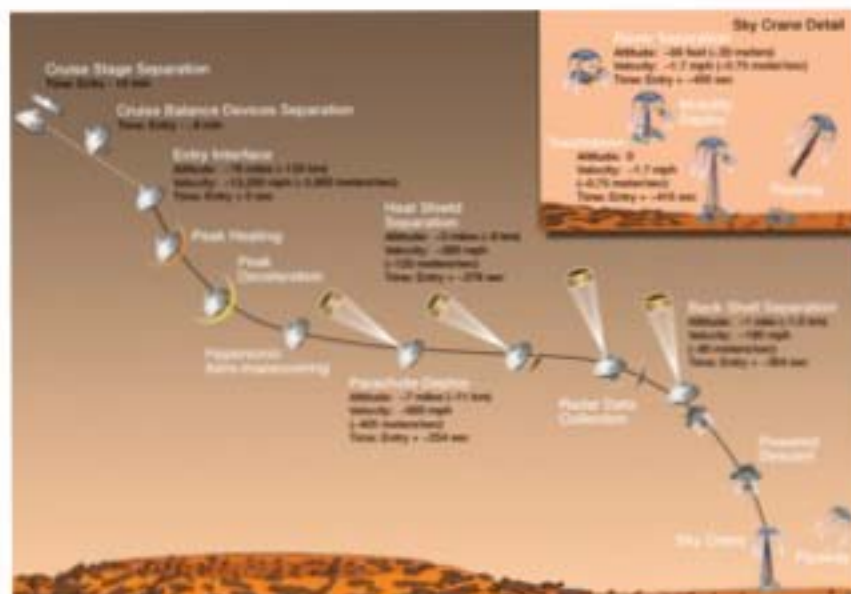


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Number Three: Human Space Exploration

- Fundamental Biology
- Entry, Descent & Landing
- Human Factors





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Number Four : Cross Cutting Initiatives

- High end computing (quantum)
- Synthetic Biology
- Innovative Partnerships
 - **DoD**
 - **Industry**
 - **International /Academic**





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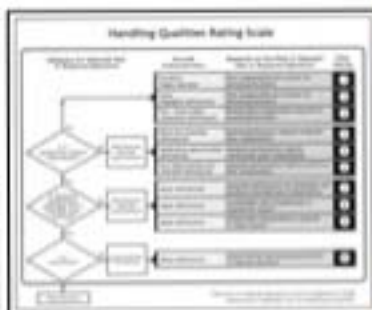


R. T. Jones

Ames Contributions to Aeronautics



Flight Research



**Cooper-Harper
Rating Scale**



Wind Tunnel Testing



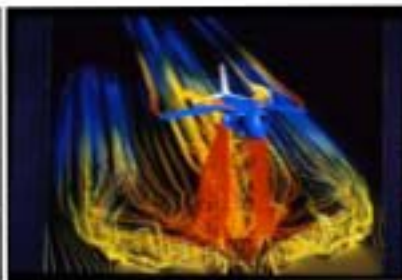
Flight Simulation



Swept Wings



Conical Camber



**Computational Fluid
Dynamics**



**Short-Haul
Aircraft**



Takeoff Research



Air Traffic Management



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Ames Contributions to Air Traffic Management



Dr. Heinz Erzberger

Products



Flight Management
Systems

1980

1970

Optimal Guidance



1973



Traffic Management
Advisor Build 1

1994



1996

Arrival
Metering



Final Approach
Spacing

2000



Future Automated ATC

Intelligent
Software



Human Factors



Field Test



1990

Simulations



Research Spectrum

Scheduling Algorithms



Benefits Analysis





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Ames Contributions to Mercury and Gemini

Blunt Body Re-entry



**Free Flight Ablation Test
Arc Jet Facility**

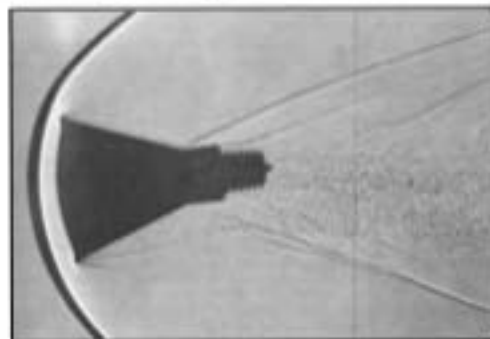
Re-entry Aerodynamics



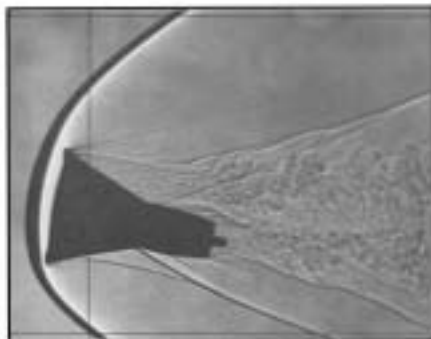
**Tektites and Trajectory Studies
Dean Chapman**



**Re-entry Airflow and Stability Pattern Studies
Hypervelocity Free-Flight Facility**



**Shadowgraph
Project Mercury Re-entry Capsule**



**Shadowgraph
Project Gemini Re-entry Capsule**



**Spacecraft Testing and Evaluation
Unitary Plan Wind Tunnel**



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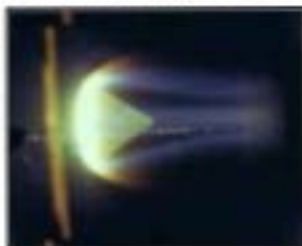


Ames Contributions to Apollo

Technology Research



**H. Julian Allen
Ames Director
During Apollo
Program**



**Free Flight Ablation
Test, Blunt Body
Re-entry Studies**



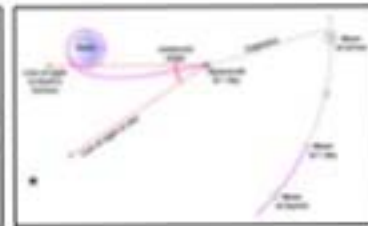
**Steerable
Parachute**



**Navigation
Simulator**



**Launch Escape
System
Unitary Plan WT**



Guidance System



**Lunar Surface
Magnetometer**



**Dr. Cyril
Ponnampерума
Analyzing
Moon Sample**

Moon Sample Analysis



Life Sciences Glove Boxes, Lunar Receiving Facility



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Ames Contributions to the Space Shuttle

Supporting Research



Lifting Bodies

Aerodynamics



Orbiter/Boeing 747
Ferry Configuration
14-foot WT

Ascent Aerodynamics & Aerothermodynamics



Exhaust Plume
Interactions
9 x 7 WT



Shuttle Abort Maneuver
14-foot WT

Thermal Protection System



TPS Materials
Development



Stagnation
Point Tests
Arc Jet

Entry Aerodynamics & Aerothermodynamics



Shadowgraph of
Bow Shock Wave
at Mach 7

CFD Simulation Results for the Shuttle Stack During Ascent



Simulation on Hyperwall

Return to Flight

Columbia Supercomputer,
Wind Tunnels,
Debris Transport,
Ascent Aerodynamics,
Thermal Protection Experts,
Thermal Analysis,
Structural Analysis,
Database management, and
Virtual Motion Simulator

Standby Support During Missions

Ames-Dryden Flight Research Center



Shuttle Landing Site (38 Landings between 1981-1994)

Flight Simulation



Vertical Motion
Simulator

Low-Speed Descent Aerodynamics



36 Percent Scale
Model 40 x 80 WT



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Ames Contributions to Astrobiology

Investigation into:

- Context for habitable environments and life
- Origins of life and its impact on the planetary environment
- Future of life in changing environments

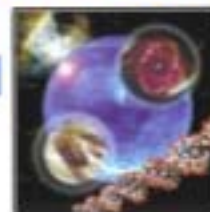
*Excerpted from 2003-2004 NAI ARC team report



SETI



Astrobiology Institute



Exobiology Branch



Dr. Harold P. Klein



Dr. Cyril Ponnamperuma



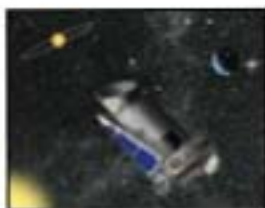
Dr. Baruch Blumberg



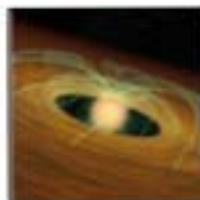
Dr. David Morrison



G. Scott Hubbard



Kepler



Spitzer Space Telescope



Airborne Science Platforms



Robots and Other Instruments



Orbiters and Probes



Earth, the Moon, Mars, and other planets



Stars



Meteors & Comets Asteroids





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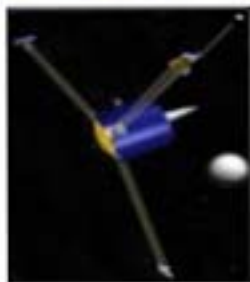
Ames Contributions to Lunar Exploration



**Apollo
1969**

Safe human landing on
the Moon and return to
Earth

- Guidance System
- Lunar Surface Magnetometer
- Blunt Body Re-entry
- Moon Sample Analysis (Lunar Receiving Facility)
- Launch Escape System



**Lunar Prospector
1998**

Spectroscopic
survey of entire
lunar surface

- Mission and Operations
- Managed Payload, Instruments, and Spacecraft Design and Development



**LCROSS
2008**

Confirm presence or
absence of water or
ice in a polar lunar
crater

- Mission and Operations
- Managed Payload, Instruments, and Spacecraft Design and Development



Constellation

Human exploration of the
Moon, Mars, and beyond

Orion CEV

- Thermal Protection System
- Aero/Aero-thermal Database
- Flight Software and Guidance, Navigation and Control

Mission Operations

- Flight Control Software
- Training Applications
- Planning and Development Tasks



**Technology and
Science Support**

Lunar Crater Observation

Exploration Life Support

Radiation Dosimetry and

Medical Sensor Technology

Space Human Factors

ISS Exploration Experiments

Piloted Spacecraft Handling

Reentry



Palmer Dyal

**Apollo
Lunar Surface
Magnetometer**

Ares I

- Integrated Systems Health Mgmt.
- Launch Abort System Software and Instrumentation
- Aero/Aerothermal Models and Analysis and Risk Assessments

**NASA Lunar
Science Institute
March 2008**



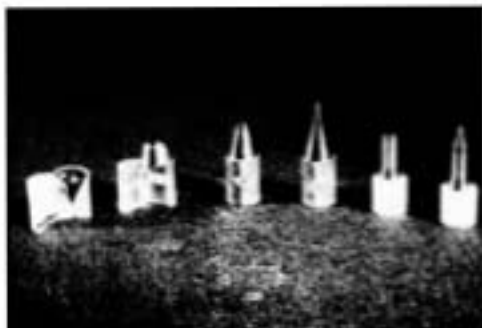
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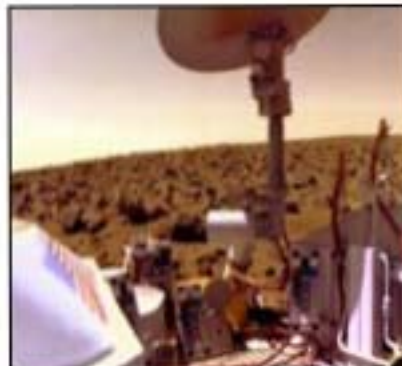
Ames Contributions to Mars Exploration



Dr. Harold P. Klein



Early Tests for Mars/Venus Entry
in
Carbon Dioxide and Nitrogen
Mixtures (Early 1960s)



Biological Investigation (Viking)



Thermal Protection Systems
(MER and MSL)



Science Operations (MER)



Mission Support Software (MER)



Landing Site Selection (MER)



Shadowgraphs showing the shock wave
shape



Human-Centered Computing and
Fatigue Countermeasures (MER)



Parachute Wind Tunnel Tests
(MER and MSL)



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Ames Contributions to MSL

Mars Science Laboratory Entry, Descent, and Landing Instrument (MEDLI)

Sophisticated plugs with multiple
temperature sensors that measure
atmospheric conditions and
performance of the heat shield



PICA Heat Shield

Mars Science Laboratory InterfaCE (MSLICE)

Software tool to plan the science
activities of the Mars rover and
maximize scientific research



Parachute test



CheMin



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Ames Contributions to Small Spacecraft



Pioneer 6-9
1965-1968

Studied the solar wind from a solar orbit.



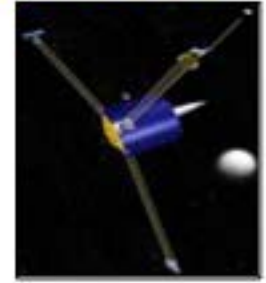
Pioneer 10 & 11
1972-1973

First man-made objects to safely pass the asteroid belt, provide detailed investigation of Jupiter and Saturn, and, leave our solar system.



Pioneer Venus
May 1978

Completed radar mapping of 93% of the planet's surface. The four probes and bus gathered data about the Venusian atmosphere.



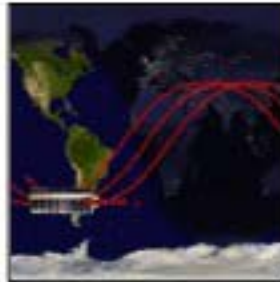
Lunar Prospector
1998

Carried out a spectroscopic survey of entire lunar surface.



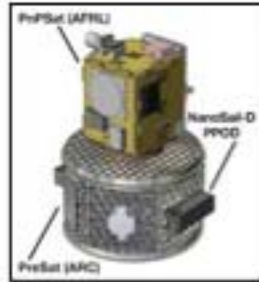
SOAREX
2004-

Conduct suborbital aerodynamic reentry experiments.



GeneSat
2006

Miniature satellite provided life support to E.Coli bacteria in orbit.



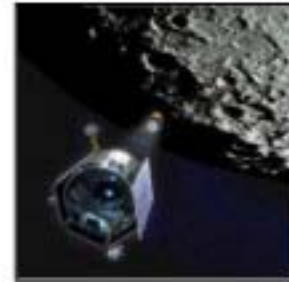
NanoSail-D/PreSat
2008

Demonstrate and validate performance of the platform.



PharmaSat
2008

Miniature satellite will carry yeast spores.



LCROSS
2008

Confirm presence or absence of water or ice in a polar lunar crater.



LADEE
2011

Assess the atmosphere and surface dust of Earth's moon.